Publishable Summary

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Project acronym: **ENLIGHT**

Project title: **Enhanced Lightweight Design**

Funding Scheme: **Collaborative Project: Large-scale integrating project**

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Periodic report: **1st ✓ 2nd ☐ 3rd ☐ 4th ☐**

Period covered: **from 01.10.2012 to 31.03.2014**

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ENLIGHT

[1] Usually the contact person of the coordinator as specified in Art. 8.1. of the Grant Agreement.
[2] The home page of the website should contain the generic European flag and the FP7 logo which are available in electronic format at the Europa website (logo of the European flag: http://europa.eu/abc/symbols/emblem/index_en.htm logo of the 7th FP: http://ec.europa.eu/research/fp7/index_en.cfm?pg=logos). The area of activity of the project should also be mentioned.

3.1 Publishable summary

One of the key societal challenges of today is the decarbonisation of the road transport. The challenge of decarbonisation must be met among others by significantly reducing the vehicles weight reversing the weight spiral of the last decades on the other hand. However the need for weight reduction in future EVs, without unduly compromising performance and safety, is even stronger since additional weight translates into either reduced driving range or in larger, heavier and more expensive batteries. Striving for reduced weight as the only objective will not necessarily result in a reduced environmental impact of the EV fleets of the future: Another two key and equally important drivers need to be pursued at the same time, namely affordability and life cycle impact minimization. Affordability is essential since it will allow for larger portion of the total EV fleet to adopt specific light-weighting solutions; and Life Cycle Impact effectively defines the total CO_2 impact over the lifetime of the vehicle.

Therefore, ENLIGHT aims to advance highly innovative lightweight material technologies for application in structural vehicle parts of future volume produced Electric Vehicles (EVs) along four axes: performance, manufacturability, cost effectiveness and lifecycle footprint. The main target is to develop viable and sustainable solutions for medium production volume EVs destined to reach the market in the next 8-12 years. In ENLIGHT each of the principal major weight-incorporating parts of a vehicle will be addressed directly by the five modules: a front module and central floor module, a front door, a sub-frame and suspension system as well as an integrated cross car beam as part of the firewall. The specific objectives of the ENLIGHT project are on holistic and integrated conceptual design and manufacturing concerning how the technologies and materials addressed (in combination with materials / forming/ joining processes coming from other previous and on-going projects) can be combined into a representative medium-volume EV by around 2020. This design is targeted to have a 20% additional weight reduction compared to the targets that are pursued in the complementary ALIVE proposal.

ENLIGHT targets an ultra-compact four-seated passenger as considered in the ELVA project. Based on this architecture, the five selected modules will be conceptually designed with respect to weight and CO2 balance over life-time. These designs will be evaluated and potential improvements assessed on vehicle level with respect to weight, safety and performance that result from the application the highly advanced material developed within ENLIGHT. The optimal combination of architecture & design, processes and materials requires a systemic technical cost modeling, ensuring sustainable solutions using LCA and accounting for externalities, while taking into account the necessary integration into the manufacturing strategy of each car manufacturer and supplier.

Within in ENLIGHT highly advanced materials such as thermoplastic matrix composite, fibre-reinforced composites, advanced hybrids and sandwich materials as well as composites based on bio-material and renewables will be developed to a stage that they are applicable at least in medium volume production. The material development will be complemented by investigating the required manufacturing and assembly technologies as well. The relevant technologies being developed or available outside of the project will complete the input for the multi-criteria decision-making process needed to select which technologies will be finally applied in the final ENLIGHT demonstrators of the five modules.

ENLIGHT advances innovative lightweight & low embodied CO2 materials and their related design, manufacturing & joining capabilities suitable for automotive industry which requires unique levels of affordability, mechanical performance and ecology. The project innovates computer-based as well as experimental validation approaches (and their combinations) to allow for a fast, efficient and reliable design process. ENLIGHT validates the solutions by means of large scale level physical demonstrators to be evaluated experimentally in combination with a full vehicle virtual design and simulation. ENLIGHT will deliver

- highly innovative lightweight / low embedded CO_2 materials for their application in medium-volume automotive production,
- design capabilities for affordable medium-volume lightweight EVs,
- manufacturing and joining capabilities for affordable medium-volume lightweight EVs,
- experimental and simulation validation environments to enable rapid & reliable multi-parameter optimization when designing with these new materials,
- LCA and economic analysis taking into account all salient factors,
- 5 demonstrator modules (front module, suspension parts, door module, components for the cockpit/firewall section and the floor section), covering different distinguishing features of purpose-designed EVs.

With this ENLIGHT will accelerate the introduction of energy efficient BEVs by taking away “range anxiety”. ENLIGHT would result in a considerable weight reduction compared to the present BEVs on the road whereby the vehicles weight correlates linear with the energy consumption. A weight reduction of 20% results in 20% less fuel consumption. As such, ENLIGHT will contribute to the green house gas reduction through lower energy consumption taken from the electricity grid, while diminishing the EU’s geopolitical oil dependence.

Besides environmental impacts ENLIGHT results are important for the European competiveness as well. The European Union is still the world’s largest car-producing area and car market, and its automotive industry is vital to Europe’s sustainable development. Europe produces 29% (2010) of the global vehicles. In order the meet the challenges arising from the new markets in Asia and the policies defined worldwide to meet the global demands, the European automotive industry must recognise the worldwide technology trends by incorporating them into their own strategy on the one hand and by driving the market growth on the other hand. Lightweight design, highly efficient engines and efficient use of energy within the vehicles are among the most important global techno-logical trends to be addressed by the European industry.

The ENLIGHT OEM partners jointly produce 54% of the vehicles in the EU-27 countries and 24% of all the vehicles in the world. In this way ENLIGHT ensures an effective direct wide scale impact on the sector through the participating OEMs and their supplier networks.

The shortest term target market segment for ENLIGHT is the segment of mid volume (~30.000 units/year) premium vehicles (in 2020), which, selling at a premium price, are more likely (initially surely) to incorporate more costly components / modules into the vehicle structure. This will allow for the maturing of these advanced lightweight technologies in real market vehicles. Further re-search, know how from first application experiences and increasing economies of scale will then lead to lower unit costs and make the advanced lightweight technologies economically viable for mass volume electric (and ICE) vehicles in the next generational leap (in 2025), thus leveraging the benefits over the whole EU vehicle fleet.

In the first reporting period the focus was on the conceptual design of the five considered modules, the development of the materials for those modules and the initial evaluation of joining and manufacturing technologies as well as on advanced testing strategies.

The objective of **WP 1** is the design of lightweight components for the common demonstrator of the SEAM cluster. The focus is on advanced materials with enhanced functions. In particular, the partners involved are developing concepts for (see Figure 1):

- a front module
- suspension parts
- a door module
- components for the cockpit/firewall section
- the floor section

Besides saving weight, also the integration of additional functions like increasing crash performance, noise and vibration properties or cooling of the integrated battery of the electric vehicle are studied.

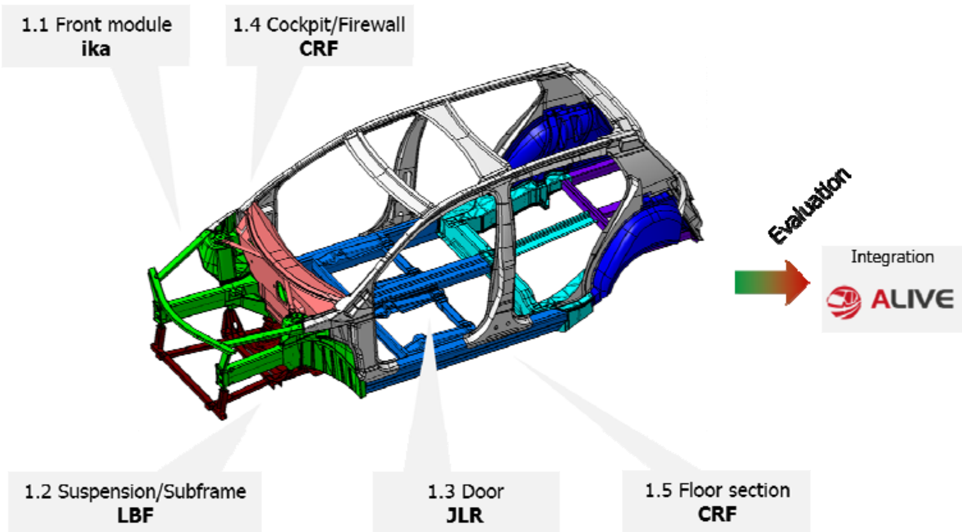

Figure 1: ENLIGHT modules as part of the ALIVE vehicle architecture

Up to now the basic concept for each module has been defined and their feasibility with respect to weight targets and manufacturing investigated. The detailed design is foreseen for the 2nd period.

WP 2 is the simulation work package of ENLIGHT. Focus of the recent project period was research on material model formulations for the considered advanced materials and joining methods that are being developed in ENLIGHT. These models will be calibrated and validated by mechanical tests in the following. It is expected that the developed material models will enable realistic predictive simulation of multi material vehicle structures focusing on fibre reinforced plastics (FRP). Besides general research on the modelling of FRP materials the simulation of special features of materials, described in the following, has been investigated.

Among others, a unit cell model for predicting wave propagation in infinite periodic structures was developed in order to improve the NVH behaviour of components. The study of unit cells allows wave manipulation: waves can be blocked through design of resonant metamaterials and waves can be focused to achieve acoustic lenses. Shape optimization is used for the design of acoustic lenses. Through developed models of finite structures, the unit cell predictions are related to finite samples to assess improvements in NVH behaviour. Additionally, material models were developed to predict the behaviour of FRP materials which change their stiffness dependent on the temperature of the material which can be influenced by an electric current.

Focusing on high strength and low ductile materials like CFRP brittle fracture is an important criterion. For this micromechanical modelling of composite materials under cyclic and high-speed loadings for automotive applications is being considered. So far, a micromechanical modelling has been developed, starting from the constituents – fibre, matrix and interface. A consistent approach has been built to determine the constituent properties using standard test methodologies. An in-depth study has been done to assess the interface characterisation mechanical properties, such as interfacial normal and shear strengths. Several micromechanical failure criteria for cyclic and high-speed loadings are currently being refined.

The objective of **WP 3** is the development of novel lightweight materials for applications in the modules designed in WP 1. The materials are to allow manufacture at medium production volumes, providing affordable vehicle solutions with added functionality and/or increased safety. The materials considered in this WP are divided into four categories: thermoplastic composites, thermoset composites, advanced hybrids and bio-materials.

The main challenge regarding the development of materials in ENLIGHT is the parallel approach of material development and design. This approach has high potential to result in innovative solutions, as the materials properties can be optimized for the application, at the same time as the parts are designed to exploit the materials properties in the best way. However, this approach is also a challenging task and requires close collaboration between material development and module design. In order to facilitate the communication within WP 3 but also between WP 1 and WP 3, various documents have been provided comprising different information about the materials and the requirements:

- A list of all considered materials has been made available for all partners, along with
- a material database comprising all available properties of the considered materials.

Both documents are updated continuously, as material development work creates new results.

- The global requirements for materials regarding use in cars have been provided by Renault as a basis to define required tests.

The material properties that are to be tested do, however, strongly depend on the materials' application and therefore a strategy to accelerate the assignment of materials to applications has been elaborated within WP3: A special version of the material list comprises the parts requirements identified by WP1 partners and for every material it is indicated how good it fulfils the different requirements. Based on this document, possible applications can be identified by the individual material suppliers in order to narrow the materials choice for every application. To further support the material choice for different applications, it was decided at the General Assembly that a rough estimation of the environmental impact of all considered materials is to be given by LCA. A strategy for such LCA has been decided and the required input for such LCA has been defined.

Material development work is at the same time proceeding at the different partners and no major deviations from the plan are expected. It is expected that the possible applications for every material can be narrowed with the above described approach. Expected input from WP1 about the prioritized properties to be tested for each application will allow the finalization of a test plan for all materials within the coming months. No major problems are expected for the preparation and testing of the materials according to this plan due to the good progress of the material development work. Results from these prioritized tests and from LCA will allow the final material choice for each application by the designers. More thorough material testing towards the specifications for the chosen application is then to be performed as a final action in WP 3 and will allow for final optimization of the design in WP 1.

WP 4 is addressing the development and the technological feasibility evaluation of innovative manufacturing, welding and assembly technologies for the multi-material concepts/modules designed in WP1. The assessment will consider also the enabling opportunity of integration of several functions into one component from the technological and economical point of view. It will result in a smaller number of parts within the overall vehicle architecture. Up to now, riveting, welding and adhesive bonding were evaluated regarding their implementation in the manufacturing process for multi materials. Additionally, hot metal gas-forming, the automation of composite material manufacturing as well as rapid stamp forming as suitable manufacturing technologies were evaluated so far.

WP 5 is supporting ENLIGHT developments with testing and characterisation activities focussing on three main attributes: fatigue, crash and NVH. Test and characterisation results will be used to assist in the validation and updating of the (multi-)material models in WP 2 and to assist in the development of new lightweight materials in WP 3 and their manufacturing in WP 4, such that the new module designs of WP 1 can be validated in WP 6. As such, WP 5 is a highly integrated WP, even outside of ENLIGHT as close interactions with FP7 projects ALIVE and MATISSE is also foreseen.

By the end of month 18, work has started on devising appropriate test strategies and performing first characterisation tests in support of WP 3. The aim is to combine static and dynamic test to accelerate the testing by adapting existing high-end test installations which will be used e.g. for dynamic NVH testing (Figure 2).

Figure 2: Example of a test rig used within ENLIGHT

The objective of **WP 7** is to apply the Life Cycle Assessment (LCA) methodology to calculate and compare the effects of the introduction of innovative lightweight materials design solutions; the environmental performances are evaluated during the whole life cycle of the vehicles ("from cradle to grave" approach). Only turning the attention from the limited analysis of the raw materials extraction to a wider analysis including manufacturing, use and End-of-Life phases, it will be possible to appraise the benefit derived from weight reduction. Because the utilisation of new materials leads to new potential problems in term of recyclability/recoverability, these issues will be faced and analysed in order to give adequate knowledge for LCA evaluations. Along with environmental analysis, also a Life Cycle Costing (LCC) model will be developed in order to assess the viability and affordability of lightweighting design solutions. Up to now, a methodological approach has been set to perform comparative LCA evaluations. A specific methodology is necessary in order to provide a consistent tool to develop LCA evaluations in the field of automotive sector, in particular eco-design solutions for electric vehicles. For this reason, the established methodology takes into account the outcomes of the E-Mobility Life Cycle Assessment Recommendations (eLCAr) project. Furthermore the LCA method will be in accordance with the international standard EN ISO

14040 and the International Reference Life Cycle Data System (ILCD). As showed in Figure 3, the system boundary includes all the life cycle phases of the ENLIGHT modules (Production, Use and End-of-life) and their relative upstream and downstream processes.

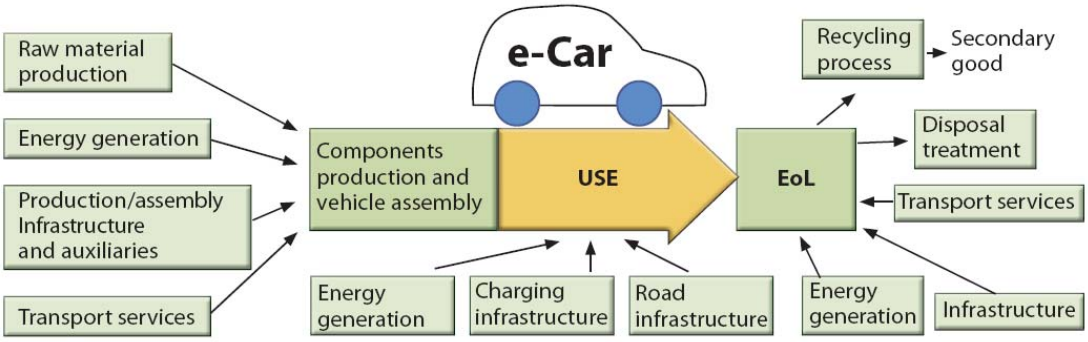

Figure 3: Summary of activities included in the system boundary of ENLIGHT modules